TWO REPORTS,

ADDRESSED TO THE

LIVERPOOL & MANCHESTER RAILWAY COMPANY,

ON THE

PROJECTED

NORTH LINE OF RAILWAY

FROM

LIVERPOOL TO THE MANCHESTER, BOLTON, AND BURY CANAL,

NEAR MANCHESTER,

EXHIBITING

THE EXTENT OF ITS CUTTINGS AND EMBANKINGS,

WITH

ESTIMATES OF THE COST OF COMPLETING THE SAID RAILWAY.

BY

CHARLES VIGNOLES, Esq.

AND

JOSEPH LOCKE, Esq.

CIVIL ENGINEERS.

LIVERPOOL:

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1835.

TO

THE DIRECTORS

Of the Liverpool and Manchester Railway.

GENTLEMEN,

IN compliance with the instructions conveyed to me through Mr. HENRY BOOTH, Treasurer of the Company, I have carefully examined copies from the plans and sections deposited with the Clerk of the Peace for the County Palatine of Lancaster, of an intended Railway from the Manchester, Bolton, and Bury Railway to Liverpool, surveyed by Mr. COMRIE, under the directions of Messrs. WALKER and BURGES, Civil Engineers, which project has been familiarly called "*The North Line.*" I beg to submit the result of my investigation of excavations and embankments, the expense and the probable time the same will occupy in execution, with an abstract of the levels and gradients.

I would premise that I have adopted for the *transverse sections* of the Road the same areas which I used upon the Wigan Railway, and which I am adopting on the Preston Line, now in course of

a quantity rather more than is contained in the Great Broad Green and Roby Embankments, on the Liverpool and Manchester Line.

Next succeeds an excavation for a mile and a half, through Bootle Hill; nearly one-half the length of this cutting will average upwards of 40 feet in depth. The contents will be 839,738 cubic yards, with uniform slopes of $1\frac{1}{2}$ to 1, but with slopes of 2 to 1 when the excavation exceeds 20 feet, the quantity will be 1,028,533 yards.

After crossing the Ormskirk Road on the level, the proposed Line would enter upon a comparatively slight cutting (through part of Fazakerley Township) of 88,933 cubic yards, followed by an embankment about $2\frac{1}{2}$ miles long, and requiring 850,212 cubic yards; and further on the Railway will fall into a length of cutting of more than three miles, whence a total quantity of 447,954 cubic yards would have to be taken.

An embankment, of a mile and upwards, would next pass the proposed Rail-road, over the low grounds of Rainford: it would contain 620,355 cubic yards, which are to be supplied from the next cutting in the same Township, producing 711,468 cubic yards, at slope of $1\frac{1}{2}$ to 1, and 852,904 cubic yards, at slope of 2 to 1, when the depth exceeds 20 feet. A short embankment, of 108,106 cubic yards, will carry on the Line over an angle of Windle Township; and the Railway would then enter on the long length of heavy excavation, extending $4\frac{1}{2}$ miles, through the Township of Billinge and Ashton.

For nearly two miles of this distance, between Chadwick Green and Downall Green, the average depth of cutting will be 78 feet, having 106 feet at the summit. This part of the excavation will be double the length and twice the average depth of the deep part of the great Kenyon cutting, on the Liverpool Line. The total amount of material to be removed in the Billinge and Ashton Hill is 4,784,289 cubic yards, at slopes of $1\frac{1}{2}$ to 1, and 5,790,510 cubic yards with slopes of 2 to 1, where the depth exceeds 20 feet. Should the ground prove to be rock, the work might be judged of *ā priori*, by considering the excavations through Olive Mount, on the Liverpool and Manchester Railway, to be extended two miles, with an approach thereto from one end of a deep cutting for three-quarters of a mile, averaging upwards of 40 feet, and by a cutting of about 18 feet in average depth for $1\frac{3}{4}$ miles at the other end.

At the termination of this very extensive excavation, at the Turnpike-road from Hindley to Ashton, the Line would enter upon an embankment to extend to Garrett Mill (1 mile east of Tyldesley Church), a distance of 7 miles, requiring 2,770,070 cubic yards. The western end of this embankment will be very heavy, and will average 50 feet in height for about a mile across the valley of the Leigh Canal, near Dover Locks, and the height for a quarter of a mile of this distance will exceed 60 feet: the slopes for this portion at least ought, in my judgment, to be augmented so as to be not less than $2\frac{1}{2}$ horizontal to 1 perpendi-

cular, which would increase the aggregate of the embankment material from the amount as stated above, to 2,886,236 cubic yards.

For about four miles beyond Garrett Mill, eastward, to near Partington-lane, the Line is over comparatively level ground; the amount of excavations being 135,134 cubic yards, and of intermediate embankments 93,670 cubic yards.

From Partington-lane to the junction of the intended Rail-road with the Manchester, Bolton, and Bury Railway, near Park House Farm, the route conducts the Line over a very formidable section, by *Irlam-o'th'-Heights*, for two miles; of which rather more than one mile would average 60 feet depth of excavation, with very nearly 100 feet in the deepest portion; a great part of this cutting would most probably have to be run out into spoil banks. The total quantity of material at constant slopes of $1\frac{1}{2}$ to 1 would be 2,429,766 cubic yards, and computing the slopes at 2 to 1 when the depth exceeds 20 feet, the aggregate cutting will increase to 2,928,799 cubic yards.

I now proceed to abstract the quantities of earthwork, prefixing the remark, that if rock should be found in the deep cuttings, no important saving of either time or expense could be expected, though the aggregate amount of absolute *materiel* might be diminished. I repeat my conviction, that *Earth-Slopes* must be made 2 to 1 when the cuttings exceed 20 feet, and the embankments sloped $2\frac{1}{2}$ to 1 when the height is 50 feet and upwards.

ABSTRACT

Of the Excavations and Embankments upon the intended Railway between the Manchester, Bolton, and Bury Canal and Railway and Liverpool.

SECTIONS OF EARTH-WORK.	LENGTH.		EXCAVATIONS.		EMBANKMENTS.	
	Miles.	Chains.	Slopes 1½ to 1 (Constant.)	Slopes 1½ to 1 in slight Cutting, and 2 to 1 where Cuttings exceed 20 feet.	Slopes 2 to 1 (Constant.)	Slopes 2 to 1 in general, & 2½ to 1 where Bankings exceed 50 feet.
Embankment from Williams-street, in Liverpool, to Bootle	1	40	.....	....	635,095	635,095
Excavations through Bootle-hill	1	55	839,738	1,028,533	.....	.....
Excavations in Fazakerley Townships ...	1	10	83,933	83,933	.....	.....
Embankments through Fazakerley and Kirkby Townships..... .	2	55	....	.....	850,218	850,218
Excavations in Kirkby and Rainford Moss	3	30	447,954	447,954	.....	....
Embankment through Rainford Township	1	25	.....	.....	620,335	620,335
Excavations in Rainford Township	1	35	711,468	852,904	..... .	.....
Embankment over Angle of Windle Township	0	35	.....	.....	108,106	108,106
Excavations through Billinge and Ashton Townships	4	40	4,729,295	5,790,510	.....	.....
Long Embankment from Hindley Turnpike-road to Garrett Mill, beyond Tyldesley Church	7	0	.....	.....	2,770,070	2,886,236
Small Excavations between Garrett Mill and Hoylehurst Brook, near Partington-lane	2	70	135,164	135,164	.....	.....
Small Embankments between ditto	1	20	.....	.....	93,670	93,670
Excavations through part of Worsley and through Pendlebury and Pendleton Townships	2	25	2,429,766	2,928,799	.....	....
Totals.....	31½ miles.		9,377,348	11,267,767	5,077,504	5,193,660
Add 10 per cent. for Consolidation.....					507,750	519,366
					5,585,254	5,713,0

To form an estimate of the time and cost of removing this great mass of material (which in the one case is upwards of three times, and in the other nearly four times as much as the whole of the earth-work, including back cuttings and spoil banks on the Liverpool and Manchester Railway), I have next abstracted the distances each portion would require to be moved, fixing the prices (as far as applicable) rather below those which have been actually contracted for on the Railways at present under execution, and putting for the longer runs, which far exceed any thing that has ever come to my knowledge, moderate sums.

ABSTRACT

Of the quantities of Earth-work upon the intended Line of Railway, with the Distance to be carried.

Cubic Yards.		Average Run or Distance carried.
635,095	From Walton and Bootle-hill to the North Shore Embankment	2000 yards.
393,438	From ditto to Fazakerley Embankment	5000 „
83,933	From Fazakerley Hall Cutting to the Fazakerley Embankment	1400 „
166,904	From Simmonswood 3-mile Cutting to the Fazakerley Embankment	2100 „
281,050	From further end of Simmonswood Cutting to the Fazakerley Embankment, allowing for consolidation.....	6100 „

Cubic Yards.		Average Run or Distance carried.
682,268	From the Rainford Cutting to make up the Rainford Embankment, and allowing for consolidation	2200 yards.
170,606	From Rainford Cutting to be run to spoil	Spoil Bank.
118,917	From Billinge and Ashton Cutting to Windle Embankment, allowing for consolidation	660 yards.
1,484,443	From Billinge and Ashton Cutting to the Leigh Canal Embankment at the Dover Locks, allowing for consolidation.....	3000 „
1,032,672	From Billinge and Ashton Cutting to the Bolton Railway Embankment, and up to Ashton Mill, allowing for consolidation	7½ miles.
3,154,478	Remainder of the Hill to be run to spoil	Spoil Bank.
103,037	From the small Excavations between Tyldesley Banks and Partington-lane, to make up the adjacent small Embankments	Short Distances.
32,097	Remainder of small Cuttings to Embankment below Tyldesley Church.....	2000 yards.
625,647	From Cutting at east end of Worsley to the Embankment behind Tyldesley Banks and Ashton Mill, allowing for consolidation	7½ miles.
2,303,152	Remainder of the Cutting to the Manchester, Bolton, and Bury Canal, to run to spoil	Spoil Bank.
11,267,767	Which, at the various prices I have estimated upon, would amount to	£586,581 14 9

The above is exclusive, however, of the purchase or damage of Land for spoil banks, and exclusive of unsoiling and resoiling, draining of slopes, &c.

The embankments being formed from the cuttings, it is known, from long experience, that only a limited quantity can be teamed or shot down from the waggons, daily. The utmost that the best regulated exertions have yet accomplished at one end or face of an embankment, within my experience or information, has not amounted to 1000 cubic yards per day; and such a quantity can only be transported over long distances, by a great capital invested by the Contractor in extra lines of rails, in waggons and other materials, in horses, and in Overseers' wages. Neither can this amount be estimated upon for more than five days in the week, as one day must be allowed for bad weather, idleness and disorder on the part of the men, and other contingencies. Thus 260,000 cubic yards is the limit of a year's work at one end of an embankment. The embankment, seven miles in length, from the Hindley Turnpike-road to Garrett Mill, will require, including a moderate allowance for consolidation, upwards of three millions of cubic yards, of which one-half would have to be carried to that portion of the valley of the Leigh Canal nearest the Ashton and Billinge cutting: and at the above daily rate it would require six years to accomplish these two miles of the western end of the embankment. If the eastern end is to be going on at the same period, the material must be brought from Pendlebury, and

waggoned a distance of from 6 to 11 miles. In any case, a million, or a million and a half of cubic yards would have to be conveyed $7\frac{1}{2}$ miles, and upwards of five millions thrown into spoil. I am not able to perceive how this portion of the line could be opened entirely for traffic under a period of seven or eight years from the passing of the Act, unless the face of the county be covered by additional millions of yards of excavations, run into spoil bank; an equal quantity of earth being obtained from side cuttings to a great depth; gaining time at an expense which I do not pretend to calculate.

The deep cuttings at Billinge and Irlam, the materials of which would have to be run into spoil, may be in some degree judged of by those persons who have seen the heavy excavations near Birmingham, for the Old Birmingham Canal, executed for lowering the summit level. A judgment also may, from that work, and from the great embankments on the Liverpool and Birmingham Junction Canal, be made by persons not professionally Engineers, of the increase of the expense of bridges, culverts, and masonry, when the cuttings and bankings are laid out on so great a scale, especially where the bridges cross obliquely.

The levels or gradients, to which according to the deposited section, the undulating surface of the natural ground would require to be reduced for receiving the upper works of the Railway, the earth-work and masonry being completed, are as follows, commencing at Liverpool. I ought previously to observe, that the starting point in Liverpool is 22 feet above the level

of Williams-street, and that mechanical power must consequently be applied to lift every ton of goods going eastward, to that height. The level of Williams-street is about 7 or 8 feet above the Dock Quays.

Gradient.	Feet per Mile.	Distances. Miles.	Distances. Chains.	Rise or Fall.	Feet.	Total Height above Starting Point of Railway at Williams-street, in Liverpool.	Total Height above Level of Quays of Liverpool Docks.	Friction and Gravity. Per Ton.
....	....	0	40	Horizontal	0	0 feet	29 feet	9 lbs.
1 in 455	12	2	47	Rise	30	30 „	59 „	14 „
1 in 1208	4⅓	2	23	Fall	10	20 „	49 „	11 „
1 in 294	18	3	10	Rise	56	76 „	105 „	17 „
1 in 880	6	2	0	Rise	12	88 „	117 „	11½ „
1 in 380	14	4	48	Rise	64	152 „	181 „	15 „
		15 M.	6 Ch.					
1 in 375	14	5	32	Fall	76	76 „	105 „	15 „
....	....	3	0	Horizontal	0	76 „	105 „	9 „
1 in 337	15	3	0	Rise	47	123 „	152 „	15½ „
....	....	2	47	Horizontal	0	123 „	152 „	9 „
1 in 303	17	2	33	Fall	42	81 „	110 „	16½ „
		16 M.	34 Ch.					
	Total...	31½ miles						
Add further distance to Manchester by the Bolton and Bury Railway of...		2½ miles.		Falling about	30	51 „	80 „	14 „
Total distance from Liverpool to Manchester...............		34 miles.						

Note.—In the last Column, the numbers applied to the *Falls*, are indicative of the power required when returning in the opposite direction.

On the proposed new Line the inclined planes are so long, and the intermediate better levels so placed, and of such extent that additional engines to assist could not be economically applied. And it is therefore evident to every one accustomed to consider the subject, that if this Line should be executed, the engines could scarcely do half their work, with the additional disadvantage of being liable to considerable retardations on the long ascents, in cases of slight accidents to the engines, which are not felt on the easy gradients of the existing Railway, whereon a locomotive may, and often does work with one cylinder, when the other is casually out of order.

I have not had any borings made on the Line of the intended Railway, nor did I consider it necessary for a general estimate. The prices are put for clay, sand, or marl. If the rock or hard material be found, a proportionate additional price must be allowed, while the quantity would be diminished. Experience has proved that the result in time and money will not be diminished, as I have before observed.

On the Liverpool and Manchester Railway, it appears that the aggregate amount of rock and earth excavations, including side cuttings and spoil banks, and the cuttings, Chat Moss, subsequent trimmings, &c. did not exceed about three millions of cubic yards.

The Inclinations on the Liverpool and Manchester Railway are as follows:—

radients.	Feet per Mile.	Distances. Miles.	Chains.	Rise or Fall in Feet.	Total Level as to Railway Starting Point at head of Tunnel.	Total Height above Dock Quays at Liverpool.	Friction and Gravity Per Ton.	Remarks.
Horizontal	....	0	20	0	123 feet below	0	9 lbs.	
1 in 48	110 feet per mile	1	10	Rise 123 feet	0	123 feet	$55\frac{2}{3}$,,	Stationary Engine
Horizontal	....	0	43	0	0	123 ,,	9 ,,	
1 in 1193	$4\frac{3}{4}$ feet per mile	5	18	Fall 25 ,,	25 feet below	98 ,,	11 ,,	
1 in 96	55 ,,	1	38	Rise 81 ,,	56 ,, above	179 ,,	$32\frac{1}{3}$,,	Additional Engine
Horizontal	....	1	70	0	56 ,, above	179 ,,	9 ,,	
1 in 90	$59\frac{1}{3}$ feet per mile	1	32	Fall 83 ,,	27 ,, below	96 ,,	34 ,,	Additional Engine
1 in 2653	2 ,,	2	41	Fall 5 ,,	22 ,, below	91 ,,	10 ,,	
1 in 896	6 ,,	6	48	Fall 39 ,,	61 ,, below	52 ,,	12 ,,	
1 in 1283	$4\frac{1}{2}$,,	5	50	Rise 23 ,,	38 ,, below	75 ,,	11 ,,	
1 in 3850	$16\frac{1}{2}$ inch. per mile	4	30	Rise 6 ,,	32 ,, below	81 ,,	$9\frac{1}{2}$,,	
		31 miles.						

The locomotive engines on the Liverpool and Manchester Railway start at an elevation of 123 feet above the Dock Quays, and have to overcome a vertical rise of 81 feet to the summit, all the rise being, however, concentrated on the inclined-plane, which is attended by an assistant engine.

Hence, it is evident, that the locomotive engine of the intended new Line would have to overcome a greater rise, by about 70 feet, than the engines have now to do on the Liverpool and Manchester Railway, and that under circumstances which admit of no additional help being given to them, with any possible degree of economy. It also appears that the summit level of the North Line, although in 106 feet cutting, would be fully as high above the Dock Quays of Liverpool as the present Railway summit is.

I can have no hesitation in stating, even taking into account the inclined-planes of the Liverpool and Manchester Railway, that it would require fully one-fifth and probably nearly one-fourth additional locomotive power to do the same work, at the same speed, on the intended "North Line," and that the liability of delay to goods and passengers would be much increased by petty derangements of the engines, slipping, &c. or putting on additional coaches or waggons, in cases of emergency; since upon inclinations of 14 to 17 feet per mile, the engines would be working up to their full power nearly, which, on the Liverpool and Manchester level, is not the case generally.

The cost of an establishment of locomotive engines, including repairs and renewals, is about £1000. per

engine per annum, working with heavy trains, and at high velocities; and consequently the additional cost of locomotive power on the proposed North Line would be from £7000. to £8000. a year above what it would cost upon the Liverpool and Manchester Railway, taking no account of the increased distance of three miles.

But against this must be set off the expense of the stationary engine, &c. at the head of the Tunnel, which is about £2000. a year. There is still £5000. a year in favour of the mode of working the present Line; demonstrating that the concentration of the heights to be overcome is more economical than the distribution of the ascent through long distances.

The masonry of a public work is always increased with the excavations and embankments: looking at the section of the projected Line, and observing the number of bridges and their position, over deep cuttings and through high embankments, it is certain the expense for masonry of all kinds will greatly exceed in cost per mile any Railway hitherto executed or projected. The crossing for the intended Railway, over the valley of the Leigh Canal, including the public Roads, Canal, Wigan Railway, and Colliery Tram Roads, will require an expensive viaduct; the various Properties and Streets laid out along the North Shore, at Liverpool, will demand numerous archways, and the occupation bridges over the deep chasms in Billinge and Pendlebury, will be very costly. The bridges on the Old Birmingham Canal, over the deep cutting, cost several thousand pounds each. The cost of the masonry on that portion of the North

Union Railway just let to respectable Contractors, is more expensive per mile than that upon any of the existing Railways, independent of the Ribble Bridge; and from a comparison of the sections, it will be found that the proportion of excavations on this Line to that on the projected North Line, is as 4 to 10:—the total on that part of the North Union Railway, for 15⅓ miles, being two millions of cubic yards, and for the projected North Line, for 31½ miles, being 10 or 11 millions.

In making the following Estimates of forming the Railway, I have taken the Contract prices of the Railways under execution; and for the iron I have assumed the weight of rails, pedestals, size of the blocks, &c. intended to be used on the North Union Railway, and which will most probably be adopted for the London and Birmingham and other Railways, and at the market price of the day.

ESTIMATES.

Earth-work as before stated	£586,582
Masonry	156,500
Land and damages	120,000
Railway laid complete, comprising Iron Rails, Chairs and Fastenings, Blocks, Sleepers, &c.; cost of Forming and Laying, Drains, Road Material; Points, Crossings, Turn-plates, &c.	158,160
Fencing, Gates, Walling, Lodges, and Roads	25,750
Preliminary Expenses and Management	50,000
Contingencies 10 per Cent.	109,699
	£1,206,691

I have not included in the above, any items for locomotive engines, coaches, waggons, stations,

repairing establishment, warehouses, or machinery. Neither does the computation extend to more than two Lines of Railway, at the termination in Liverpool. Nor does it include the expense of the $2\frac{1}{2}$ miles along the Manchester, Bolton, and Bury Railway, into Salford.

I do not consider that the sum of £250,000. would do more than meet all these necessary outlays.

I beg to be understood, that in drawing up the preceding statements and estimates, I have endeavoured to do so as calmly and deliberately as possible, and without any exaggeration: having reference always to the estimates, quantities, and extent, and the contract prices for the work of the Railways I am about to commence, and of those I have lately finished.

The levels of the proposed Railway, and calculation of the power which locomotive engines can exert thereon, are within every Engineer's capacity to test.

I do not express any opinion as to the propriety of adopting similar levels in this or in other cases; the sole object of this Report being in pursuance of your instructions, to contrast the actual facts relative to the existing Liverpool and Manchester Railway, with the projected North Line.

I am, Gentlemen,

Your very obedient Servant,

CHARLES VIGNOLES, C. E.

Trafalgar Square, London,
21st Jan. 1835.

TO

HENRY BOOTH, ESQ.

Treasurer of the Liverpool and Manchester Railway Company.

DEAR SIR,

IN accordance with your request on behalf of the Liverpool and Manchester Railway Company, I have examined the plans of the projected North Railway, with a view of furnishing you with an estimate of the probable cost of the Works therein contemplated, and the result of my investigation will be found in the Report which I now beg to lay before you.

The Line, which is 31½ miles long, commences in Williams-street, Liverpool, and forms a junction with the Bolton and Bury Railway, within 2½ miles of Manchester; the total distance to Manchester, therefore, will be 34 miles.

In estimating the cost of Works of this description, it will be apparent that the most important items are Excavations, Embankments, Bridges, and Land,

and to these I would more particularly direct your attention.

The quantity of earth to be removed will depend on the angle at which the slopes are to be formed; and this again depends on the sort of earth, and the depth of the excavations; and without accurate borings, it is not easy to fix the requisite slope in each locality. In ordinary cases, a slope of 2 feet horizontal to 1 foot perpendicular might be allowed, and for the smaller works 1½ to 1; but in excavations similar to those on the projected North Line, varying from 50 to 100 feet deep, and extending for several miles, it is difficult to fix the slope at which the sides would not slip; I have however calculated the quantities at 2 to 1, as well as at 1½ to 1, and presuming that some portion of the material will be rock, in which the sides may be made steeper, and the remainder clay, sand, or marle, I have thought it prudent, notwithstanding the great extent of deep cuttings, to take the average or medium between these quantities.

The embankments are all taken with slopes of 2 to 1, allowing 10 per cent. for consolidation.

	Cubic yards.
Cuttings, with slopes 2 to 1...	11,338,215
Ditto 1½ to 1...	9,196,307
Average, or medium ...	10,267,261 @ 13d. = £556,143.

Of this quantity, about 5 millions will require to be thrown into spoil, and the remainder to be carried to the embankments, of which latter portion about 3 millions must be taken nearly 6 miles.

The Bridges on this Line will be very expensive, for, in addition to the increase in cost arising from the deep cuttings and high embankments, the number required will be about one-half more than are now built on the Liverpool and Manchester Railway. The most costly will be that across the Wigan and Leigh Canal, and the turnpike-road and valley at Dover Brook, where the embankment is upwards of 60 feet high, and where a Bridge similar to the Sankey Viaduct will be required.

The quantity of Land is ascertained from the medium slopes, and the price I have taken at £120. per acre. To this, however, is added an extra price for the Land in Liverpool, as well as the cost of 20,000 square yards for a station; but my estimate does not include any Buildings to be erected, nor the cost of forming the Railway from the junction with the Bolton and Bury Line to Manchester, nor any sum for a station at Manchester; neither does it include the cost of engines, coaches, and waggons, necessary for working the line.

The rails, chairs, blocks, and other items composing the general estimate, are made on the same scale as those contemplated on the Grand Junction Railway.

ESTIMATE.

Including, then, the amount for excavations already stated, and the land, bridges, rails, chairs, blocks, forming, fencing and draining, but EXCLUSIVE of the cost of the Railway from the Bolton and Bury

Canal to Manchester, and EXCLUSIVE of the cost of the Manchester station, warehouses and offices both at Liverpool and Manchester, and the whole establishment of engines, coaches and waggons, I estimate the cost of completing the projected North Railway at the sum of £1,112,642. or about £35,000. per mile.

That this amount, great as it is, does not exceed the proportion to which, from the magnitude of the works, it is entitled, will be seen by referring to some of the Railways that now engage the public attention; and from which it will appear that, costly as some of them are admitted to be, they are all greatly exceeded by that now under consideration.

I have before stated that large excavations and embankments influence directly the quantity of land and the magnitude of the bridges; and in comparing the following table, it will be well to bear this in mind, particularly since these items form so large a portion of the entire estimate:—

London and Southampton Railway Cutting	200,000	cubic yards per mile
London and Birmingham ditto, exclusive of Tunnels.....	108,000	,,
Liverpool and Manchester ditto ...	100,000	,,
Grand Junction.....	70,000	,,
Projected North Line	320,000	,,

And it is a remarkable fact, that in the last-described line, which is $31\frac{1}{2}$ miles long, to the junction with the Bolton and Bury Railway, there is above 50 per cent. more earthwork than is met with on the

whole of the Grand Junction Railway, which is nearly 80 miles long.

The time required for executing works of this description depends on the facility of applying labour over a large space; where this can be done, a long cutting may be made as expeditiously as a short one. A large excavation may be made by working at intermediate points, as well as at the extremities; but an embankment can only be formed at the two ends, and its progress will therefore depend on the facility with which earth from the adjacent cuttings can be supplied. The embankments on the projected North Line, as has been stated, do not much exceed one half the excavations, yet it so happens that the former will require the longest time in making.

One embankment, from 15 to 60 feet high, is 7 miles long, and will require nearly $3\frac{1}{4}$ millions of cubic yards, and even with very great exertion will take 7 years to complete it. You are no stranger to the activity displayed in making the Broad Green Embankment, which was the greatest work on the Liverpool and Manchester Line;—the inducements and rewards given by the Directors, and the almost total disregard of cost, for the purpose of saving time; and yet this embankment does not contain one-fifth of $3\frac{1}{4}$ millions, notwithstanding which 3 years were required for its formation.

(I calculate on 250 working days per annum, and 1000 cubic yards per day brought to each end of the embankment; this continued for $6\frac{1}{2}$ years will give

$250 \times 1000 \times 2 \times 6\frac{1}{2} = 3{,}250{,}000$ cubic yards, and to this I add 6 months for preparation, finishing off, and laying permanent rails.)

You will naturally suppose that with works so enormously expensive, this Railway when made will be level, or at least will possess such inclinations as to afford great mechanical advantages; this, however, is not the case, for although there is no inclination so great as the Rainhill inclined plane, still the summit level is quite as high as Rainhill. I do not wish, however, to dispose of this part of the investigation by an opinion merely, and have therefore taken the trouble to calculate the proportionate amount of power required to drag one ton of goods from Liverpool to Manchester by the Line now projected, and by that already existing, and the results will be seen in the tables annexed.

It will be apparent that the resistance on a Railway is generally composed of two elements, friction and gravity, and the power required to overcome this resistance will, in ascending, be equal to the sum of these elements, and in descending, to their difference. The aggregate amount, also, of mechanical force expended on a Railway is equal to the sum of the products of the resistances, and the respective lengths of the planes. If, therefore, we multiply the lengths of the planes by the resistances offered in each, we shall obtain a number that will represent the whole mechanical force required on the Line, and a standard by which any other Line may be compared. On

this principle, I have made the annexed tables of comparison.

The length from the junction of the projected Line with the Bolton and Bury Railway to Manchester, I have assumed to be $2\frac{1}{2}$ miles, and descending at the rate of about 10 feet per mile. I have not had very accurate means of ascertaining this, but believe it to be very nearly the true distance.

TABLE,

Showing the length, inclination, and resistance on each of the planes on the Line of the projected North Railway, and the number of lbs. which, hanging over a pulley, and moving through a space of 66 feet, will convey one ton of goods from Liverpool to Manchester. Friction taken at 9 lbs. per ton.

Length in Chains.	Rise in Feet.	Fall in Feet.	Rate of Inclination.	Resistance in lbs.	Total Resistances in lbs.
0	22	.....	Perpendicular rise at Liverpool.	2240	$746\frac{2}{3}$
40	.....	.....	Level	9.00	360
207	30	.....	1 in 455	13.92	$2881\frac{1}{2}$
183	.....	10	1 in 1208	7,15	$1308\frac{1}{2}$
250	56	.....	1 in 294	16.62	4555
160	12	.....	1 in 880	11.55	1848
368	64	.....	1 in 380	14.89	$5479\frac{1}{2}$
432	.....	76	1 in 375	3.03	1309
240	.....	.....	Level	9.00	2160
240	47	.....	1 in 337	15.64	$3753\frac{1}{2}$
207	.....	.....	Level	9.00	1863
193	.....	42	1 in 303	1.61	$310\frac{3}{4}$
2529	.....	.....	.....	.....	$26,175\frac{1}{2}$
200	Distance from the Junction of the Bolton and Bury line to Manchester		1 in 500	4.50	900
2720 or 34 miles.	231	128	Average Resistance...	10.00	$27,075\frac{1}{2}$

TABLE,

Showing the same from Crown-street and from Wapping to Manchester by the present Railway.

	Length in Chains.	Rise in Feet.	Fall in Feet.	Rate of Inclination.	Resistance in lbs.	Total Resistances in lbs.
	43	.....	.....	Level	9.00	387
	418¾	.....	25¼	1 in 1094	6.95	2910
	117¾	80½	.....	1 in 96	32.33	3807
	150	.....	.....	Level	9.00	1350
	112½	.....	83	1 in 90	.....	.....
	201½	.....	4⅔	1 in 2858	8.22	1656
	528	.....	39½	1 in 883	6.46	3411
	450	22¾	.....	1 in 1300	10.72	4824
	349	5½	.....	1 in 4257	9.52	3323
Result from Crown-street to Manchester.	2370½	108¾	152⅓	Average Resistance	9.14	21,668
Add Tunnel & Wapping Station.	15	.....	.....	Level	9.00	135
	90	123¼	.....	1 in 48	55.66	5,009
Result from Wapping to Manchester.	2475½ or 30$\frac{75}{80}$ miles	232	152⅓	Average Resistance...	10.83	26,812

If, instead of adding the old Tunnel, we add the new one from the Cattle Market, then for the number 26,812 we shall have, 21,668 + 3076 = 24,744. To place these results together, viz.—

From Crown-street to Manchester 21,668
Wapping to Ditto 26,812
Lime-street to Ditto 24,744
And by the projected North Line 27,075

And from which we find that the latter is worse than the Line from Crown-street by 20 per cent., from

Wapping by 1 per cent. and from Lime-street by 9 per cent.

It also appears that on the present Line from Crown-street to Manchester (about $29\frac{5}{8}$ miles) the average resistance is $9\frac{1}{7}$ lbs. per ton, which very nearly corresponds with a dead level; and on the newly projected Line (about 34 miles) the resistance is about 10 lbs. which is equal to a rise of about $2\frac{1}{2}$ feet per mile for the whole distance. This view of the case is of some importance, showing as it does, that notwithstanding the inclined plane at Rainhill, the aggregate amount of power required from Crown-street to Manchester is very little more than it would have been had the line been perfectly level.

It is not, however, the only way in which the question should be considered, for although a Line in the aggregate may be favourable, it is nevertheless desirable to avoid any partial inequality in the levels; for it is necessary that every engine should be powerful enough to overcome the resistance on the greatest inclination it may have to surmount. Suppose an engine that on a level is able to drag 200 tons; it will on an inclination of 1 in 1300 (which is the greatest rise from Crown-street to Manchester, setting aside the inclined plane, where the engines are assisted,) drag 168 tons; and if we apply the same engine to the projected North Line, where the greatest rise is 1 in 294, we shall find that it will not drag more than 108 tons.

This reduction in the load can only be made up by employing an assistant engine on the plane, which, however, would be still more disadvantageous; for the rise of 1 in 294 is nearly $3\frac{1}{4}$ miles long; and an assistant engine would, in aiding each train, traverse a space of $6\frac{1}{2}$ miles. Besides, there are two other planes $7\frac{1}{2}$ miles long, rising on an average 1 in 360, upon each of which an engine would be required to assist the train, and they would have to traverse a space of 15 miles; thus, then, we should have an assistant engine traversing two-thirds of the whole distance to Manchester, in order to save one-third of its maximum load. Nor, in this instance, would one-third be saved; for, besides those enumerated, there are other planes which would prevent the engine from taking that load. It is clear, therefore, that this Line must be worked without assistant engines, and on the previous assumption, each train cannot exceed 108 tons in weight; whilst, on the present Railway, where the inclined plane is only $1\frac{1}{2}$ mile long, the assistant engine in each trip, itself traversing a space of 3 miles, enables the train to be loaded to the extent of 168 tons, and this addition of 60 tons, which is more than one-third of the whole load, is obtained at the cost of an assistant engine, traversing only one-tenth of the whole distance.

The above view of the case admits of some modification. Trains may be despatched frequently with such loads as to enable the engines to surmount the

greatest plane; after which they may travel with greater ease, and thereby reduce the consumption of fuel. Assistant engines are a constant expense, without the certainty of a constant trade. These considerations might, under certain circumstances, have some weight; but when an uniformly great trade is to be carried on, their importance ceases.

In the tables it will be seen, that the aggregate amount of resistance on the Line from Wapping, approaches nearest to that on the projected Line; it should, however, be borne in mind, that in the Tunnel alone the resistance amounts to one-fourth of the whole resistance from Crown-street to Manchester. This arises from the steepness of the inclination in the Tunnel, which is worked by a fixed engine, and thus the locomotives, having the advantage of starting from a high, and consequently a favorable level, are enabled to drag trains of 168 tons weight.

The economy of working the Tunnel by a fixed engine will, I think, be admitted, particularly when it is considered, that by thus concentrating the rise at one point, and rendering the remainder of easy and gradual ascents, the locomotives are enabled to do so much more effective work; and it is important also to bear in mind, that more than one-half the whole number of trains that leave Liverpool daily, start from the high level, and that therefore the additional expenditure of power in the Tunnel is only required for the remaining portion.

The question of distributing the levels, or, as it is

termed, graduating the Line of any Railway, is by far the most important for the consideration of an Engineer; and as there is uo one principle applicable to all cases, each must be judged in connection with the circumstances attendant upon it. Without desiring, therefore, to do more than make a comparison between the two Lines under present investigation, I am of opinion that the traffic on the Liverpool and Manchester Railway is more economically carried on than it would have been with levels distributed like those on the projected North Line, even without the additional advantage of being three miles shorter.

In conclusion, permit me to state that after a careful and detailed investigation of the merits of this projected Line, I am of opinion, that the statements and calculations submitted in the foregoing Report are formed upon a moderate scale; and that should the work ever be executed, the difficulties to be surmounted, whether estimated in quantities, time, or money, will be found to have been rather under than over-rated.

I am,

Dear Sir,

Your obedient Servant,

JOSEPH LOCKE.

Liverpool, Jan. 17, 1835.